Open surgical and endovascular treatment of superior vena cava syndrome caused by nonmalignant disease

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Objectives: **The purpose of this study was to evaluate the role of endovascular and open surgical reconstructions in patients with superior vena cava (SVC) syndrome caused by nonmalignant disease.**

Methods: **Clinical data from 32 consecutive patients who underwent endovascular or open surgical reconstruction of central veins because of symptomatic benign SVC syndrome between November 1983 and June 2001 were retrospectively reviewed.**

Results: **The study included 17 male and 15 female patients (mean age, 38 years; range, 5-69 years). Presenting symptoms were head fullness (n = 26), dyspnea or orthopnea (n = 23), headache (n = 17), or dizziness (n = 11); physical signs were head swelling (n = 31), chest wall collateral vessels (n = 29), facial cyanosis (n = 18), or arm swelling (n = 17). Etiologic factors included mediastinal fibrosis (n = 19), indwelling catheter (n = 8), idiopathic thrombosis (n = 4), or post-surgery (n = 1). Two patients were heterozygous for factor V Leiden; 1 patient had antithrombin III deficiency. Twenty-nine patients underwent surgical reconstruction with 31 bypass grafts: spiral saphenous vein (n = 20), superficial femoral vein (n = 4), human allograft (n = 1), or expanded polytetrafluoroethylene (ePTFE, n = 6). Eleven patients underwent percutaneous transluminal angioplasty or stenting; 3 primary and 8 secondary endovascular procedures were performed to treat graft stenosis (n = 7) or occlusion (n = 1). There were no early deaths. Five early graft failures in 3 ePTFE grafts and 2 bifurcated vein grafts (thrombosis, n = 4; stenosis, n = 1) were successfully treated with open surgical revision. Over a mean follow-up of 5.6 years (range, 0.4-16.6 years) in surgical patients, 17 additional secondary interventions were performed in 8 patients, 14 endovascular and 3 surgical. Primary, assisted primary, and secondary patency rates of surgical bypass grafts were 63%, 79%, and 85%, respectively, at 1 year, and 53%, 68%, and 80%, respectively, at 5 years. Graft patency was significantly higher in vein grafts compared with ePTFE grafts (P = .02). Mean follow-up after percutaneous transluminal angioplasty or stenting was 3.1 years (range, 1 day–11.7 years). Twelve secondary endovascular interventions were performed in 6 patients (primary group, 3 of 3; secondary group, 3 of 9 grafts in 8 patients) to maintain patency in 11 of 12 reconstructions. Mean follow-up in the entire patient cohort was 5.3 years (range, 0.4-16.6 years). In 79% of patients symptoms had resolved or were significantly improved at last follow-up.**

Conclusions: **Surgical treatment of benign SVC syndrome is effective over the long term, with secondary endovascular interventions to maintain graft patency. Straight spiral saphenous vein graft remains the conduit of choice for surgical reconstruction, with results superior to those with bifurcated vein and ePTFE. Endovascular treatment is effective over the short term, with frequent need for repeat interventions. It does not adversely affect future open surgical reconstruction and may prove to be a reasonable primary intervention in selected patients. Patients who are not suitable for or who fail endovascular intervention merit open surgical reconstruction. (J Vasc Surg 2003;38:215-23.)**

Benign disease is a rare cause of superior vena cava (SVC) syndrome, accounting for only 22% of cases.[1,2] About half of affected patients (11%) have mediastinal fibrosis.[3-5] However, the exponential increase in use of indwelling central venous catheters and cardiac pacemakers over the last two decades has resulted in more patients with SVC obstruction of benign etiology. In this group of relatively young patients with normal life expectancy, a durable method of treatment is desirable. Traditional management is open surgery, with bypass grafting from the innominate vein or jugular vein to the SVC or right atrial appendage.[6-15]

Endovascular therapy with balloon angioplasty (percutaneous transluminal angioplasty [PTA]), and in recent years with stenting of the SVC, has been performed with increasing frequency.[16-21] This is accepted as the mainstay of treatment to relieve SVC obstruction due to malignant disease, keeping in mind the short life expectancy of these patients. The role of endovascular therapy in SVC syndrome of nonmalignant etiology is undecided, because long-term durability of this method of treatment remains to be assessed. The literature reports 90% to 100% initial

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Table I. Signs and symptoms of superior vena cava syndrome of benign origin in 32 patients

	No. of patients	*%*
Symptom		
Feeling of fullness in head or neck	26	81
Dyspnea on exertion or orthopnea	23	72
Headache	17	53
Dizziness or syncope	11	34
Visual problems	8	25
Cough	7	22
Nocturnal oxygen requirement	3	9
Proteinlosing enteropathy	1	3
Sign		
Head and neck swelling	31	97
Large chest wall venous collateral vessels	29	91
Facial cyanosis	18	56
Arm swelling	17	53
Pleural effusion	2	6

success rates, with good short-term secondary patency rates of up to 85% at 1 year in small series of patients.[17,19,22-24]

We evaluated the role of endovascular and surgical reconstruction in contemporary management of SVC syndrome caused by nonmalignant disease. We assessed long-term clinical results of surgical treatment, and feasibility of and short-term outcome after endovascular interventions performed to treat benign SVC syndrome at our institution.

PATIENTS AND METHODS

Clinical data for 32 consecutive patients with SVC syndrome caused by nonmalignant disease treated at the Mayo Clinic over 18 years from November 1, 1983, to June 30, 2001, were retrospectively analyzed. Data collected included details of preoperative clinical status, noninvasive and invasive evaluation, operative and endovascular procedures, post-procedure surveillance, early and late adjunctive procedures, and clinical outcome during follow-up.

On the basis of venographic pattern of SVC obstruction, patients were classified into four groups with the classification of Stanford and Doty.[25] All surgical patients with bypass grafts underwent imaging before discharge from the hospital, and all patients had at least one return visit at 3 to 6 months after surgery or endovascular treatment. Patients with no return visit within the last 6 months were contacted by telephone to determine follow-up clinical status. Post-treatment clinical outcome was evaluated in all patients and graded according to the classification scheme proposed by the Subcommittee on Reporting Standards in Venous disease[26]: +3, complete relief of symptoms, +2, mild symptoms of chronic venous disease, +1, clinical improvement, or 0, no clinical change.

Statistical analysis. Statistical analysis was performed in the surgical group of 29 patients. In 2 patients who underwent two bypass procedures sequentially, only the first graft was included in the analysis. The Kaplan-Meier method was used to estimate graft survival with respect to patency for three end points: survival free of assisted primary patency, secondary patency, and any intervention to treat occlusion.[27] The date of operation was the starting point of the analysis. For each analysis, grafts were classified as patent or occluded, only on the basis of objective evidence on radiologic imaging studies, ie, computed tomography (CT), magnetic resonance imaging (MRI), or venography. For the end point of loss of primary patency, a graft requiring assistance to maintain patency (assisted primary) was counted as an event on the date of assistance. For the end point of intervention to treat occlusion, assistance to maintain patency was also counted as an event. The 95% confidence interval was calculated at 1-year, 3-year, and 5-year survival estimates. Univariate assessment of risk factors for each of the three survival end points was performed with a log-rank test.[28] $P < .05$ was considered statistically significant.

Survival analyses were also performed to account for all 31 grafts in the 29 patients, with Cox proportional hazards models, adjusting for correlated data between 2 grafts in the 2 patients with multiple grafts. These results were similar to those of the original analysis of 29 grafts (1 graft per patient) and led to the same conclusions. Hence the simpler analysis of 29 grafts is reported. Descriptive data, however, include all 31 grafts for completeness. Statistical analysis was not performed on data for the 3 patients who underwent primary endovascular interventions (PTA with or without stenting of the SVC), because of the small number.

RESULTS

Patients

Seventeen male patients and 15 female patients (median age, 38 years; range, 5-69 years) with SVC syndrome of nonmalignant cause who underwent surgical or endovascular intervention were included in the study. All patients had persistent signs and symptoms of SVC obstruction despite medical management and physical measures to decrease venous congestion of the head and neck. Median duration of symptoms was 14 months (mean, 20 months; range, 3-72 months). The most common symptoms of SVC syndrome were head and neck fullness, and dyspnea on exertion or orthopnea (Table I). The most frequently encountered signs included head and neck swelling and chest wall collateral vessels. One 5-year-old boy had signs of SVC obstruction and severe protein-losing enteropathy secondary to compromised drainage of the thoracic duct as a result of high central venous pressure. At birth, he had undergone excision of a mediastinal tumor (benign teratoma) along with a segment of SVC and right atrium.

Mediastinal fibrosis was the cause of SVC obstruction in 19 patients (59%), and central venous thrombosis in 12 patients (38%) (Table II). PTA and stenting of the SVC had been attempted in 9 patients elsewhere, before enrollment in the present study, and was successful in 7 patients, with subsequent reocclusion, and unsuccessful in 2 patients. Two patients had undergone previous failed surgical SVC reconstruction, ie, replacement of the SVC followed post-

Table II. Cause of benign superior vena cava syndrome in 32 patients

	No. of patients	*%*
Mediastinal fibrosis	19	59
Histoplasmosis	10	31
Nonspecific mediastinal fibrosis (sclerosing medistinitis)	6	19
Nonspecific mediastinal fibrosis (granulomatous disease)	2	6
Post–radiation therapy	1	3
Venous thrombosis	12	38
Indwelling central venous catheter	5	16
Pacemaker wires	2	6
Ventriculoatrial shunt	1	3
Hypercoagulable state	1	3
Idiopathic	3	9
Surgical excision	1	3
Total	32	100

Table III. Graft material for 31 grafts in 29 patients with surgical reconstruction*

	No. of patients	*%*
Autologous vein	24	77
Spiral saphenous vein	20	65
Straight graft	17	55
Bifurcated graft	2	6
Straight graft plus reimplantation opposite innominate vein	1	3
Superficial femoral vein	4	13
Reversed vein graft	3	10
Spiral vein graft	1	3
Iliocaval allograft	1	3
Expanded polytetrafluroethylene	6	19
Total	31	100

*Two patients received 2 bypass grafts each.

operatively by tight stenosis resistant to PTA in 1 patient, and pericardial patch angioplasty of the SVC followed by a right innominate vein to right atrium spiral vein graft in the other patient. Risk factors included a history of deep venous thrombosis (DVT) in 8 patients (25%), heterozygosity for factor V Leiden in 2 patients, and antithrombin III deficiency in 1 patient. Seven patients (22%) had hypertension, 3 patients (9%) had diabetes, and 14 patients (44%) were smokers.

Preoperative evaluation

Preoperative evaluation included bilateral upper extremity venography in all patients. Thirty patients (94%) underwent CT of the chest, and 7 patients (22%) underwent MRI. Duplex ultrasound (US) scanning of the internal jugular veins was performed in 24 patients (75%). On the basis of venographic findings, SVC obstruction was classified as type I (≤90% stenosis of the SVC with antegrade azygos blood flow) in 3 patients (9%), type II (>90% SVC stenosis or occlusion with antegrade azygos blood flow) in 5 patients (16%), type III (>90% SVC stenosis or occlusion with reversal of azygos blood flow) in 13 patients (41%), and type IV (occlusion of SVC and major tributaries including azygos veins) in 11 patients (34%).

Mediastinoscopy and biopsy was performed preoperatively in 9 patients with mediastinal fibrosis; thoracotomy or thoracoscopy and biopsy was performed in 3 patients. In all patients with mediastinal masses a lymph node biopsy specimen was obtained intraoperatively before bypass grafting. One patient with acute on chronic central line–related thrombosis underwent thrombolytic therapy to provide inflow into an internal jugular to right atrial appendage bypass graft.

SVC reconstruction

Open surgery. The technique of autologous spiral saphenous vein bypass grafting was as described previously.[7,8,29] The saphenous vein is harvested and opened longitudinally, and valve leaflets are excised. The opened vein is wrapped around a 32F or 36F polyethylene chest tube, and the edges are stapled or sutured with 7.0 continuous monofilament nonabsorbable suture, interrupting the suture line every three-quarter turn. The length of saphenous vein harvested to create a graft of sufficient length is determined according to the equation proposed by Chiu et al[30] in their original experiments, $l = RL/r$, where r and l are radius and length of saphenous vein, and R and L are radius and length of the spiral vein graft.

Thirty-one bypass grafts were performed in 29 patients. Reconstruction was performed with autologous spiral saphenous vein grafts (SSVG) in 20 patients (65%), ie, 18 straight grafts and 2 bifurcated grafts (Table III). Superficial femoral vein (SFV) was the conduit in 4 patients, and expanded externally supported polytetrafluoroethylene (ePTFE, 10-16 mm diameter) in 6 patients. Human iliocaval vein was used in 1 patient with sclerosing cholangitis and mediastinitis, who underwent concomitant orthotopic liver transplantation. The grafts originated from the internal jugular vein (n = 17) or innominate vein (n = 14) and were anastomosed centrally to the SVC (n = 18) or right atrial appendage (n = 13). All grafts were imaged before patients were discharged. At discharge, 26 of 29 patients were receiving oral anticoagulation therapy with warfarin sodium (target international normalized ratio, 2 to 3).

Two patients received 2 grafts sequentially. One patient required straight SSVGs from each innominate vein to the right atrial appendage because of persistent symptoms after placement of the first graft (Fig 1). Both grafts were patent at last follow-up 4½ years postoperatively. In the other patient a thrombosed ePTFE graft was replaced with an SSVG graft at 1 year and remains patent after 2 years. Only the first graft in each of these patients was included in the statistical analysis.

Endovascular treatment. Endovascular interventions were performed in 11 patients. Three patients with type II SVC lesions due to histoplasmosis were treated primarily with PTA and stenting of the SVC. Palmaz stents (Palmaz 308; Cordis, Johnson & Johnson, Warren, NJ) were used

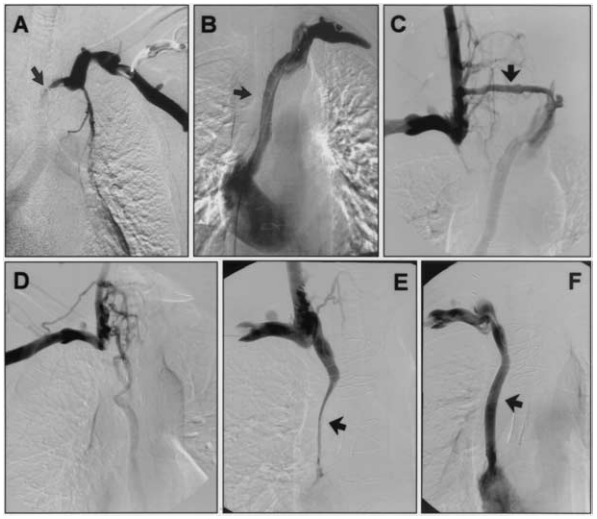


Fig 1. A, Venogram 10 months after placement of left innominate vein to right atrial appendage spiral saphenous vein graft in a 46-year-old man with mediastinal fibrosis shows severe stenosis *(arrow)* at the proximal anastomosis. **B,** Venogram 6 months after Wallstent *(arrow)* placement confirms widely patent stent and graft. **C,** Venogram of right to left internal jugular crossover graft *(arrow)* performed 16 months later because of persistent right arm and neck swelling. **D,** Early occlusion of crossover graft at 2 months. **E,** Venogram 6 months after placement of right innominate vein to right atrial appendage spiral saphenous vein graft shows external compression of the distal graft *(arrow)*. **F,** Venogram obtained after Wallstent *(arrow)* placement. Both grafts remain patent 4 years later.

in 2 patients, and a 12 mm Wallstent (Boston Scientific, Medi-Tech, Natick, Mass) was used in 1 patient. Endovascular interventions were also performed to maintain patency of 9 grafts in 8 patients in the open surgical group. These included PTA alone in 4 grafts, and PTA plus stenting in 5 grafts (10-12 mm Wallstents, n = 4; Palmaz 308 stent, n = 1). Patients received oral anticoagulants postintervention for a minimum of 3 months.

Initial diagnostic venography was performed with simultaneous injection of contrast medium in bilateral superficial arm veins. The interventions were performed with a standard transjugular or transfemoral venous Seldinger technique, insertion of a 7 to 10 mm sheath, and crossing the stenotic lesion in the SVC with a guide wire and 5F catheter. Pressure gradient across the lesion was measured before and after intervention to ensure a satisfactory result. Balloon dilation was performed with 10 to 14 mm balloon catheters, and was followed by deployment of the chosen stent across the lesion in patients with residual stenosis.

Early results

Mortality and morbidity. There were no in-hospital or early (30 days) deaths. In 2 patients in whom the SFV was harvested, acute DVT of the popliteal vein developed. A mediastinal hematoma in 1 patient compressed the SSVG and required evacuation. In a fourth patient, with concomitant excision of a large retrosternal goiter, bilateral vocal cord paralysis developed, and prolonged ventilator dependence necessitated tracheostomy.

Patency of reconstruction. Five early repeat interventions were performed to maintain graft patency. Three ePTFE grafts demonstrated thromboses in the early postoperative period. All underwent thrombectomy, and patch angioplasty of the proximal anastomosis was performed in 1 graft. Both bifurcated SSVG grafts demonstrated early complications. Partial thrombosis of 1 graft was successfully treated with thrombectomy and revision of the side limb anastomosis. Thrombosis of the side limb of the other graft was treated with thrombectomy and reimplantation; however, this graft demonstrated early recurrent thrombosis. All grafts, except one limb of a bifurcated graft, were patent at discharge. Nonsignificant (<50%) stenosis was noted in 5 grafts at postoperative imaging before discharge. Thirty-day primary patency was 84%, assisted primary patency was 87%, and secondary patency was 100%. In the 3 patients who underwent primary PTA and stenting of the SVC, primary patency was 100% at 30 days.

Late results

Mortality. Mean clinical follow-up in the surgical group was 5.6 years (range, 0.4-16.6 years). Follow-up after endovascular intervention in 11 patients (3 primary and 8 secondary interventions in bypass grafts) was 3.1 years (range, 1 day–11.7 years). During follow-up 3 patients died of unrelated causes: 1 patient died of bronchogenic carcinoma 9 years after SSVG bypass to treat central line–related thrombosis with complete relief from symptoms; 1 patient died of unknown cause after remaining asymptomatic for more than 8 years after SSVG because of pacemaker wire–related thrombosis; and 1 patient died of long-standing complications related to tuberculous peritonitis 17 months after placement of an ePTFE graft to treat central line–related thrombosis. Four patients were lost to follow-up at 6, 19, 24, and 70 months, respectively, after surgical treatment.

Patency of reconstruction. ***Open surgery.*** Postoperative graft surveillance with venography was performed at 3 to 6 months, and then at 9 to 12 months in most patients. Thereafter, grafts were imaged noninvasively with CT (n = 33) or MRI (n = 5); venography was reserved for patients with recurrent symptoms or known stenosis. In later years of the study, the second venography was sometimes replaced with CT or MRI. On 68 late postoperative venograms, mild or moderate stenosis was found in 12 grafts, severe stenosis in 11 grafts or limbs, and occlusion in 1 graft. Duplex US scanning was performed in 24 instances; graft patency was indirectly inferred from the flow pattern in the internal jugular vein because the graft in the mediastinum was not directly visualized with this method. In no instance was final patency for statistical analysis based on a duplex US scan. On one occasion graft occlusion was confirmed by ultrasound alone in a patient in whom no further intervention was planned.

Mean duration of follow-up for graft patency (based on last imaging) was 3.2 years (range, 4 days–10 years). During follow-up 9 grafts required secondary interventions (high-grade stenosis, n = 7; partial thrombosis, n = 1; occlusion, n = 1). Six of 7 high-grade stenoses occurred within the first year (between 3 and 10 months) after operation, and 1 occurred at 37 months. Three of these patients had nonsignificant stenosis at discharge from the hospital. The 7 stenosed vein grafts (6 SSVG, 1 SFV) underwent endovascular interventions (PTA, n = 3; Wallstent, n = 4). In all but 1 patient high-grade stenosis was accompanied by recurrence of symptoms. Thrombolysis and PTA of the internal jugular vein reestablished patency in the partially thrombosed ePTFE graft. The occluded ePTFE graft was replaced with SSVG.

Five grafts eventually occluded during follow-up (ePTFE, n = 3; SSVG, n = 1; SFV, n = 1). Both vein grafts were repeat surgical reconstructions in patients with failed surgical bypass grafts before enrollment in this study, and no further intervention was attempted. One occluded ePTFE graft was replaced with an SSVG, which remains patent at 2 years.

One-year, 3-year, and 5-year cumulative primary patency rates for 29 surgical grafts were 63% (95% confidence interval [CI], 48-85), 53% (95% CI, 36-78), and 53% (95% CI, 32-78); assisted primary patency rates were 79% (95% CI, 64-95), 68% (95% CI, 51-90), and 68% (95% CI, 48-90); and secondary patency rates were 85% (95% CI, 72-100), 80% (95% CI, 64-98), and 80% (95% CI, 61-98) (Fig 2, *A*). Patency rates were significantly higher for SSVG compared with ePTFE grafts: 1-year and 4-year cumulative primary patency rates were 67% (95% CI, 49-91) and 67% (95% CI, 42-91) versus 50% (95% CI, 23-100) and 17% (95% CI, 17-100), respectively ($P = .02$). Secondary patency rates were 90% (95% CI, 78-100) and 90% (95% CI, 73-100) versus 67% (95% CI, 38-100) and 50% (95% CI, 16-100), respectively ($P = .02$) (Fig 2, *B*).

Endovascular treatment. Mean duration of follow-up for patency (based on last imaging) was 2 years (range, 1 day–10 years). Venography was performed in 11 patients during follow-up, 5 for surveillance and 6 because of recurrent symptoms. Secondary interventions were performed in all 3 patients treated primarily with PTA and stenting: 1 intervention in 2 patients and 4 interventions in 1 patient (Fig 3). All secondary interventions were performed because of recurrent stenosis associated with recurrent symptoms. One patient chose to undergo SSVG at another institution 19 months after initial stenting rather than repeated endovascular interventions. The fifth intervention in a 38-year-old man was complicated by pericardial tamponade, which responded promptly to pericardial drainage.

In the secondary endovascular intervention group (8 patients), 5 of 9 grafts were patent at last follow-up without further intervention; 1 graft became occluded, and the remaining 3 grafts required further endovascular interventions (1, 2, and 4 interventions, respectively).

Outcome

Mean duration of follow-up for clinical outcome in all patients was 5.6 years (range, 0.4-16.6 years). At last follow-up or death, symptoms in 79% (95% CI, 60-92) of patients had resolved or were significantly improved (Fig 4). All patients with occluded grafts had recurrent symptoms. Only 1 patient, with the factor V Leiden gene and a patent graft, had no improvement of symptoms.

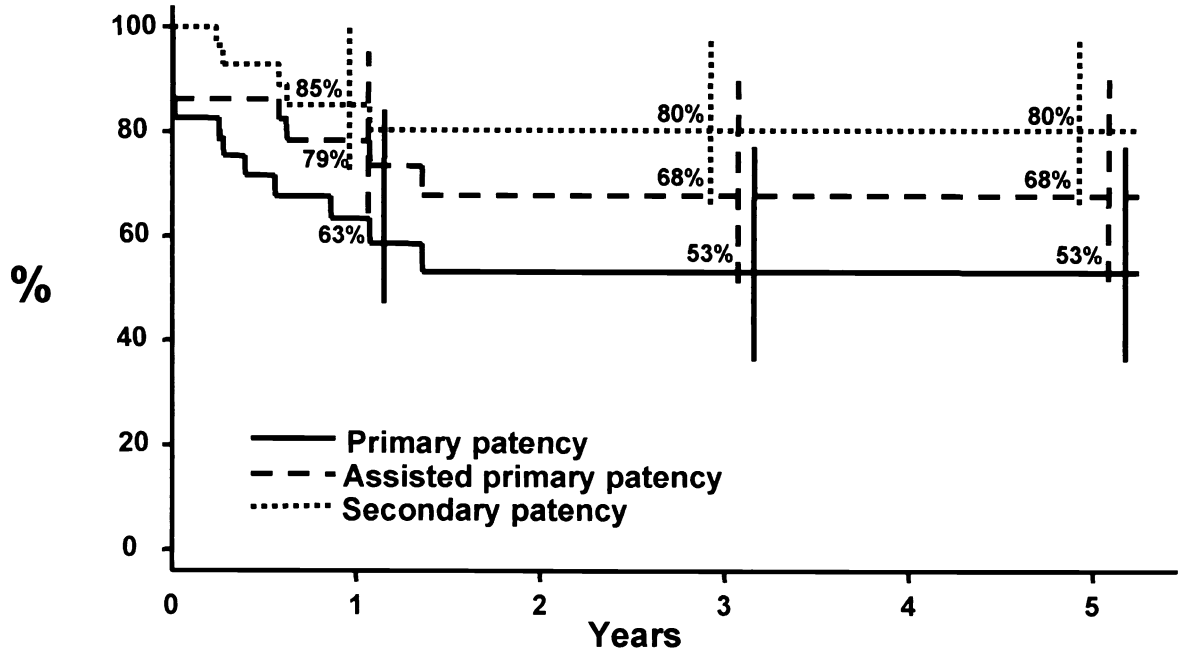
Risk factor analysis

Univariate analysis identified only ePTFE graft as a factor associated with poor primary and secondary graft patency (Fig 2, *B*). Other preoperative factors, ie, gender, age, type and cause of SVC obstruction, previous PTA or stenting, pressure gradient across the lesion, and intraoperative graft blood flow measurements, had no significant effect on outcome relative to graft patency.

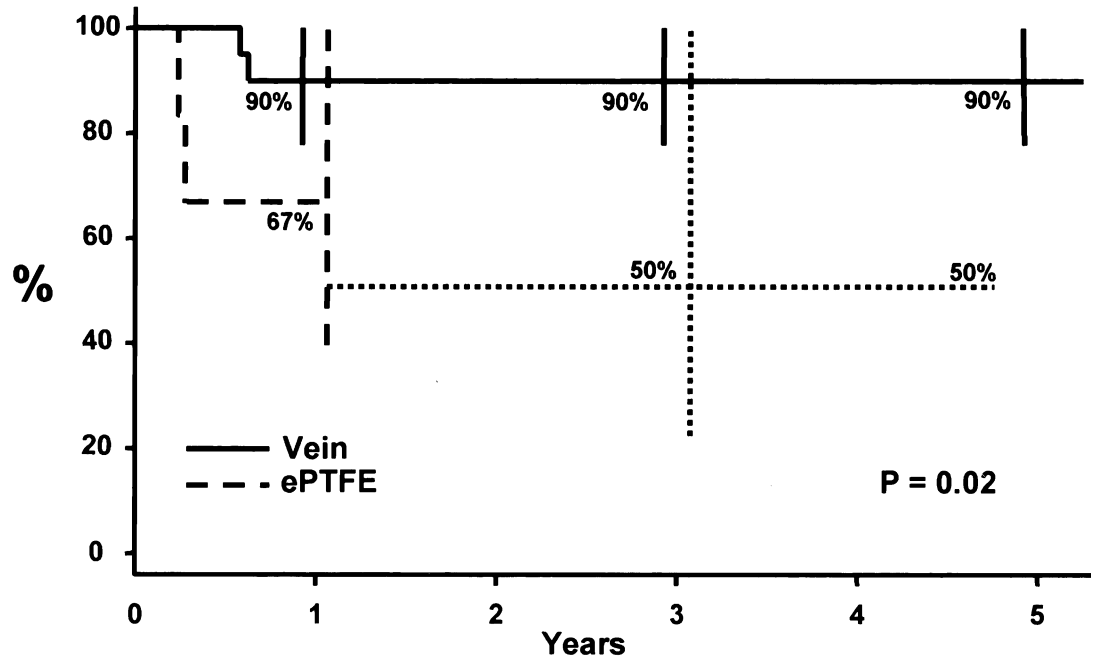
DISCUSSION

Endovascular intervention with PTA and stenting is the treatment of choice for patients with SVC syndrome due to malignant disease with symptoms unresponsive to radiation therapy and chemotherapy.[17,21-13,31] Surgical intervention has been the mainstay of treatment of benign SVC syndrome since the first SVC bypass graft half a century ago,[5] with good long-term results. However, given that SVC syndrome of nonmalignant origin accounts for only a small proportion of cases, the total experience remains small. Doty et al[11] reported excellent long-term patency and clinical results of SSVG in 16 patients. We have reported our experience with bypass grafting in 19 patients.[10] Success with PTA and stenting in malignant SVC syndrome, and increasing sophistication of endovascular techniques and devices have raised the question of whether endovascular treatment can replace surgery as the primary method of management of benign SVC syndrome as well.[22,23,32] This question is especially relevant today, with the escalating incidence of iatrogenic thrombosis of the SVC.

Surgical reconstruction of the SVC caused by benign disease has been associated with excellent long-term results.[6-9,11,12] Although the first reconstructions were performed with SFV,[5] since the description of the technique of spiraling the saphenous vein by Chiu et al[30] the SSVG has been the most popular conduit. Doty et al[6] first adopted the technique, and in 1982 reported excellent graft patency and freedom from symptoms. Their larger experience reported in 1999, consisting of 16 SSVGs placed to treat benign SVC syndrome, documented 88% long-term graft patency and excellent clinical results at a mean follow-up of 10.9 years.[11] The results of the present series confirm these results, with 90% long-term patency in the 23 vein grafts (SSVG, SFV, and allograft iliac vein). SSVG has been our preferred conduit of choice. Straight SSVG is associated with the most rewarding results; concomitant bilateral reconstructions attempted early in our experience resulted in early and late complications. We have since shied from bilateral reconstructions and found that collateralization



Patients at Risk						
1° patency	29	16	11	10	8	6
Assist 1° patency	29	20	13	12	10	8
2° patency	29	22	14	13	11	9



Patients at Risk						
Vein graft	23	18	13	12	10	9
ePTFE graft	6	5	2	2	2	

Fig 2. A, Cumulative primary, assisted primary, and secondary graft patency after open surgical bypass in 29 patients. SEM < 10% for all time points. **B,** Cumulative secondary patency after placement of 23 vein grafts and 6 expanded polytetrafluoroethylene *(ePTFE)* bypass grafts to treat superior vena cava obstruction. *Dotted line* represents SEM > 10%.

across the midline is adequate to decompress both sides with a single graft in most patients.

The SFV is a good second choice for graft conduit, and others have performed SVC reconstruction with SFV.[5,13,33] Concerns about distal thrombosis at the harvest site and chronic venous insufficiency remain; DVT developed in 2 of 4 of our patients at the distal SFV and popliteal vein, with long-term sequelae in one. Similar experience has been reported by others.[33] Clagett et al,[34] in addition to reporting 7 cases of major venous reconstruction (2 to treat SVC syndrome) with SFV have the largest experience with harvesting SFV for arterial reconstructions. Mid-term follow-up in 61 patients revealed only mild signs of chronic venous insufficiency in fewer than a third of patients, despite evidence of outflow obstruction and mild reflux on noninvasive venous evaluation.[35] These results, however, may not be directly applicable to the present group of patients with SVC occlusion, especially that caused by spontaneous or catheter-induced thrombosis. Nonetheless, it is the logical conduit in patients with unavailable or inadequate saphenous vein.

Although graft patency and clinical results were significantly poorer with ePTFE compared with vein in the present series, it remains the best prosthetic material for use in the venous system. Wisselink et al[15] reported 100% patency at 1 year for ePTFE bypass grafts placed to treat central vein occlusion in 6 patients receiving hemodialysis. A brachial arteriovenous fistula for dialysis present preoperatively in 5 of these patients may have contributed to the excellent patency by augmenting graft blood flow. We have documented better results with short, large-diameter ePTFE bypass grafts for iliocaval reconstruction in the setting of both benign and malignant disease.[8] Dartevelle et al[36] and Magnan et al[14] reported excellent patency with ePTFE reconstruction of the SVC confined to the mediastinum after resection of malignant tumors. Five of 6 ePTFE grafts in the present series originated in the neck, and the small size of the internal jugular vein precluded use of large-diameter grafts.

All high-grade graft stenoses occurred within the first year postoperatively, and half of these were mild stenosis present on the first postoperative surveillance venogram. Regardless of the treatment method, the discovery of all stenoses was accompanied by recurrence of symptoms except in one patient. Although graft patency cannot be automatically inferred from freedom from symptoms, on the basis of these data, imaging after the first year need be performed only in patients with symptoms or in patients without symptoms but with known nonsignificant stenosis. Similar views have been expressed by Doty et al.[11]

Open surgery has been the primary method of treatment of symptomatic SVC obstruction of nonmalignant etiology origin at our institution since the mid-1980s, with PTA and stenting used secondarily to maintain patency of vein grafts. Encouraging results with these endovascular interventions over the last decade prompted us to use primarily PTA or stenting in selected patients in the last few years. Initial attempts at treating benign SVC syndrome

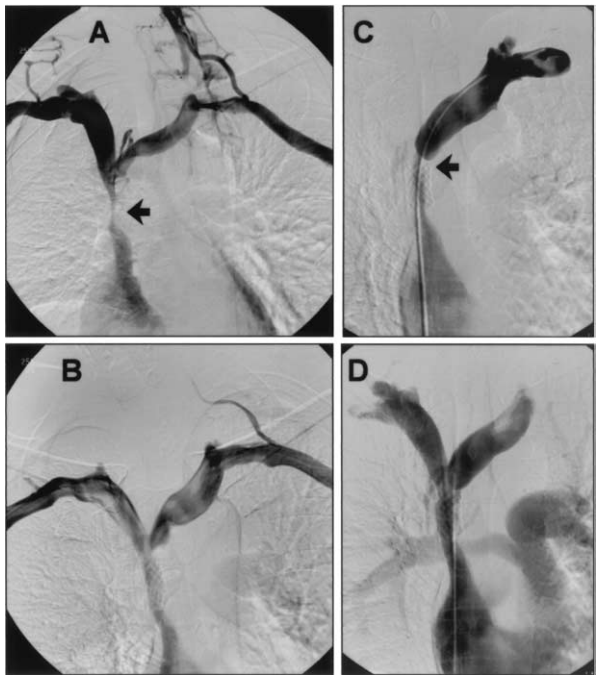


Fig 3. A, Venogram shows type II superior vena cava obstruction *(arrow)* due to mediastinal fibrosis in a 38-year-old man. Successful placement of a Palmaz stent resulted in immediate resolution of symptoms. **B,** Venogram 14 months after stent palcement shows high-grade stenosis of the left innominate vein proximal to the stent. This was successfully treated with balloon angioplasty. **C,** Venogram 8 months later shows recurrence of stenosis *(arrow)*. **D,** Venogram after balloon angioplasty to treat stenosis of left innominate vein and stent shows widely patent stent. Patient has undergone two additional balloon angioplasty procedures over 10 months to maintain patency.

with endovascular means involved PTA alone, with early recurrent stenosis caused by elastic recoil or compression from surrounding fibrosis.[37-39] In the early 1990s, occasional cases of stent deployment to treat pacemaker wire–induced thrombosis were reported, but repeated interventions were required to maintain patency in the short term.[18,20,24,40-45] Early experience was with Gianturco Z stents, which were subsequently modified by Rosch et al[43] to create a multibody design that minimized stent migration. Availability of the more flexible Wallstents and Palmaz stents in larger sizes added to the versatility of endovascular treatment. In 1996 Dondelinger and Trotteur[46] presented a series of 20 patients with stents with a secondary patency rate of 80% after mean follow-up of 16 months. Qanaldi et al[19] reported 12 patients treated with Wallstents; one symptomatic recurrence occurred at 2 months over mean follow-up of 11 months. All 3 patients in our series treated primarily with PTA and stenting required at least one repeat intervention. Despite excellent early success and prompt relief of symptoms, the need for repeated interventions makes acceptance of this method of treatment difficult in this group of young, otherwise healthy patients. Longer

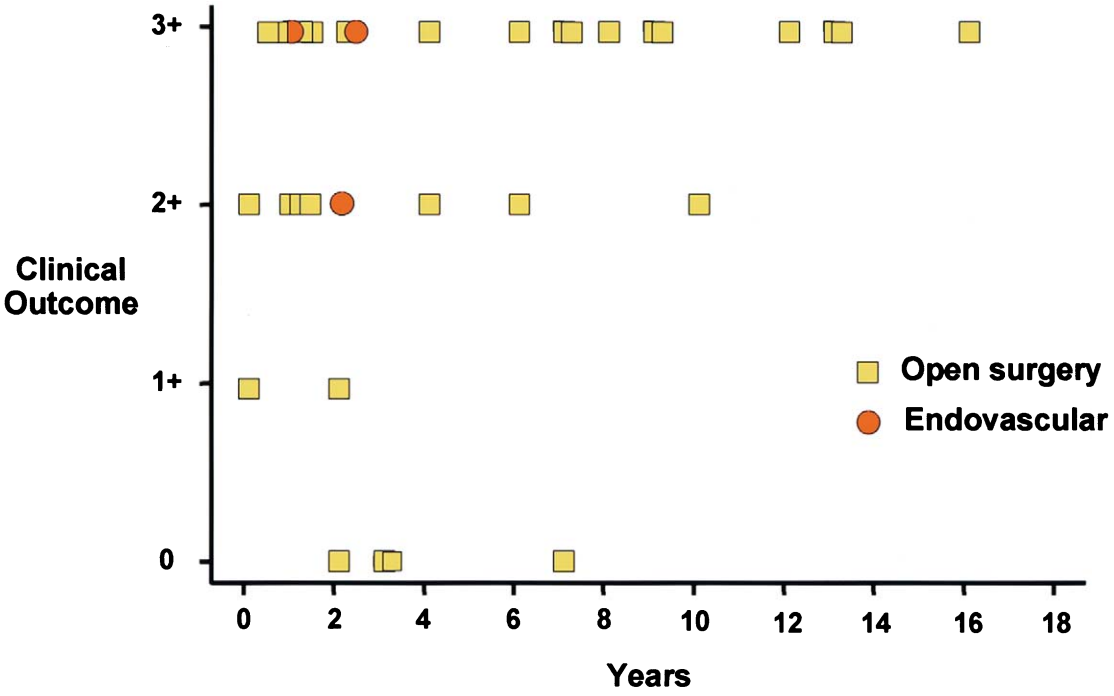


Fig 4. Clinical outcome scores at last follow-up in 32 patients with superior vena cava syndrome due to nonmalignant disease. Twenty-nine patients underwent open surgical treatment; 3 patients underwent primary endovascular treatment.

follow-up in a larger number of patients is required to address the suitability of endovascular treatment as a permanent solution for benign SVC syndrome.

Surgical treatment of benign SVC syndrome is effective over the long term, with secondary endovascular interventions to maintain graft patency. Straight SSVG remains the conduit of choice for surgical reconstruction, with results superior to bifurcated vein and ePTFE. Endovascular treatment is effective in the short term, with frequent need for repeat interventions. It does not adversely affect future open surgical reconstruction, and may prove to be a reasonable primary therapeutic intervention in selected patients with suitable anatomy. Patients who are not suitable for or who fail endovascular intervention merit open surgical reconstruction.

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